

CLAIMS

1. Method of forming a nozzle in a nozzle plate for an ink jet printhead, the nozzle having a nozzle inlet and a nozzle outlet in respective opposite faces of said nozzle plate, the method comprising the steps of:

5 directing a high energy beam towards said nozzle plate; introducing divergence into said beam; thereafter directing said beam at a single aperture of a mask, thereby to shape said beam; and thereafter passing said beam through beam converging means prior to impingement on the face of said nozzle plate in which said nozzle outlet is formed, thereby to form a
10 nozzle, the nozzle outlet being conjugate through said beam converging means with said single aperture;

characterised in that

the step of introducing divergence into said beam comprises splitting
15 said beam into a number of sub-beams, each sub-beam having divergence, the origin of divergence of each sub-beam lying apart from the point at which the respective sub-beam is created by splitting; the sub-beams thereafter being passed through further beam converging means prior to being recombined and directed through said single aperture of a mask,
20 wherein the dimensions of the section of said recombined beam directly prior to impinging the plane of said mask are substantially equal to the dimensions of the aperture in said mask.

2. Method according to claim 1, wherein the step of splitting the beam into a number of sub-beams comprises passing said beam through an array of lenses

25 3. Method according to claim 2, wherein said array comprises cylindrical lenses.

4. Method according to any preceding claim, wherein the origin of divergence of each sub-beam lies ahead of said mask.

5. Method according to claim 4, wherein the origin of divergence of each sub-beam lies between the point at which the respective sub-beam is created by splitting and said mask.

5 6. Method according to any preceding claim, wherein said mask is located at a distance from said further beam converging means equal to the focal length of said further beam converging means.

10 7. Method according to any preceding claim, wherein said beam is split by passage through an array of optical elements to create an array of sub-beams; said array of sub-beams being thereafter directed towards first reflecting means for reflecting towards second reflecting means, said second reflecting means reflecting towards said nozzle plate; the positional relationship of said first and second reflecting means being such that a parallel beam impinging on said first reflecting means is reflected from said second reflecting means as a converging beam; the arrangement of said optical elements being such that all incoming sub-beams are directed by said first reflecting means towards said second reflecting means, thereafter to impinge on said nozzle plate.

15 8. Method according to any preceding claim, wherein said high energy beam is split by passage through an array of optical elements to create an array of sub-beams, said array of optical elements having a greater width in 20 a first direction than in a second direction orthogonal to said first direction, with said first and second directions lying perpendicular to the direction of impingement of said beam on said array; thereby to form a nozzle having a bore with an angle of taper relative to the nozzle axis in a direction 25 corresponding to said first direction that is greater than the angle of taper of the nozzle bore in a direction corresponding to said second direction.

9. Method according to any preceding claim, wherein said high energy beam is directed at a planar reflecting surface lying at an angle to said first

direction, said surface being arranged so as to reflect said beam towards further beam reflecting means so arranged as to both invert said beam and direct said beam along an axis collinear with said first axis extending in a first direction; said surface and further reflecting means being fixedly located relative to one another, thereby to form an assembly, and rotating said assembly about said first axis; said beam thereafter impinging on said nozzle plate, thereby to form a nozzle.

10. Method according to any preceding claim, wherein the power of said high energy beam is initially held low and is increased with increasing depth of the nozzle formed in said nozzle plate.

11. Method according to any preceding claim, wherein a further mask is interposed between the mask and the beam converging means

12. Method of forming a nozzle in a nozzle plate for an ink jet printhead, the nozzle having a nozzle inlet and a nozzle outlet in respective opposite faces of said nozzle plate and a nozzle bore having an axis; the method comprising the steps of: directing a high energy beam towards said nozzle plate; introducing divergence into said beam, and thereafter passing said beam through beam converging means prior to impingement on said nozzle plate, thereby to form a nozzle;

~~wherein characterised in that~~

the step of introducing divergence into said beam comprises passing said beam through an array of optical elements to create an array of sub-beams, each sub-beam having divergence, the origin of the divergence of each sub-beam lying apart from the respective optical element; said array of sub-beams having a greater width in a first direction than in a second direction orthogonal to said first direction, said first and second directions lying perpendicular to the direction of impingement of said beam on said array; thereafter passing said array of sub-beams through beam converging means prior to their impingement on the nozzle plate, thereby to form said

nozzle; the angle of taper of the nozzle bore relative to the nozzle axis in a direction corresponding to said first direction being greater than the angle of taper of the nozzle bore in a direction corresponding to said second direction.

5 13. Method according to claim 12, wherein the sub-beams impinge on that face of the nozzle plate in which the nozzle outlet is formed, the nozzle tapering from nozzle inlet to nozzle outlet.

a 14. Method according to claim 12 ~~or 13~~, wherein the array of optical elements is rectangular.

a 10 15. Method according to claim 12 ~~or 13~~, wherein a mask is Diaced ahead of said array of optical elements.

a 16. Method of forming a nozzle in a nozzle plate for an ink jet printhead, the nozzle having a nozzle inlet and a nozzle outlet in respective opposite faces of said nozzle plate, the method comprising the steps of:

15 directing a high energy beam towards said nozzle plate; introducing divergence into said beam; and thereafter passing said beam through beam converging means prior to impingement on said nozzle plate, thereby to form a nozzle;

a ^{wherein} ~~characterised in that~~
20 the step of introducing divergence into said beam comprises passing said beam through an array of optical elements to create an array of sub-beams, each sub-beam having divergence, the origin of the divergence of each sub-beam lying apart from the respective optical element; said array of sub-beams being thereafter directed towards first reflecting means for
25 reflecting towards second reflecting means, said second reflecting means reflecting towards said nozzle plate; the positional relationship of said first and second reflecting means being such that a parallel beam impinging on said first reflecting means is reflected from said second reflecting means as

a converging beam; the arrangement of said optical elements being such that all incoming sub-beams are directed by said first reflecting means towards said second reflecting means, thereafter to impinge on said nozzle plate.

- 5 17. Method according to claim 16, wherein the sub-beams impinge on that face of the nozzle plate in which the nozzle outlet is formed, the nozzle tapering from nozzle inlet to nozzle outlet.

- a 18. Method according to claim ~~16 or 17~~, wherein said first and second reflecting means each comprise a reflecting surface that is a surface of revolution.

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19. Method according to claim 18 wherein the reflecting surface of said first reflecting means faces away from said nozzle plate.

- a 20. Method according to claim ~~18 or 19~~, wherein the mean radius of the reflecting surface of the first reflecting means is less than the mean radius of the reflecting surface of the second reflecting means.

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- Sub a³ 21. Method according to any of claims 16 to 20, wherein said arrangement of optical elements is such that no sub-beams from optical elements located at the centre of said array are reflected by said first and/or second reflecting means.

- 20 22. Method according to claim 21 wherein optical elements located at the centre of said array are masked.

- Sub C¹ 23. Method of forming a nozzle in a nozzle plate for an ink jet printhead, the nozzle having a nozzle inlet and a nozzle outlet in respective opposite faces of said nozzle plate, characterised by the steps of:

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directing a high energy beam having a first axis extending in a first direction

towards said nozzle plate; directing said beam at a first reflecting surface lying at an angle to said first direction, said surface being arranged so as to reflect, said beam towards a second, ^{and other} reflecting surface so arranged as to both invert said beam and direct said beam along an axis collinear with said first axis extending in a first direction; said first ^{and second} surfaces being fixedly located relative to one another, thereby to form an assembly, and rotating said assembly about said first axis; said beam thereafter impinging on said nozzle plate, thereby to form a nozzle.

24. Method according to claim 23 wherein the reflecting surfaces each comprises a discrete member.

25. Method according to claim 24, wherein said discrete member is a high reflectance dielectric mirror.

26. Method of forming a nozzle in a nozzle plate for an inkjet printhead, the nozzle having a nozzle inlet and a nozzle outlet in respective opposite faces of the nozzle plate; the method comprising the step of directing a high energy beam at the face of the nozzle plate in which said nozzle outlet is to be formed, whereby the power of said high energy beam is initially held low and is increased with increasing depth of the nozzle formed in said nozzle plate.

27. Method according to claim 26 wherein the power of the high energy beam is held low until the nozzle outlet has been formed.

28. Apparatus for use with the method of claim 1, and comprising a source of a high energy beam, mask means having a single aperture and beam converging means, characterised by an array of optical elements for splitting said beam into a number of sub-beams each having divergence, the origin of divergence of each sub-beam lying apart from the plane of said array;

and further beam converging means adapted to recombine said sub-beams; said array and further beam converging means being positioned relative to said mask means such that the dimensions of the section of said recombined beam directly prior to impinging the plane of said mask are substantially equal to the dimensions of the aperture in said mask.

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29. Apparatus for use with the method of claim 12, and comprising a source of a high energy beam; an array of optical elements for creating an array of sub-beams each having divergence, the origin of the divergence of each sub-beam lying apart from the respective optical element; said array of sub-beams having a greater width in a first direction than in a second direction orthogonal to said first direction, said first and second directions lying perpendicular to the direction of impingement of said beam on said array; and beam converging means adapted to converge said sub-beams on the nozzle plate.

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30. Apparatus for use with the method of claim 16, and comprising a source of a high energy beam; an array of optical elements for creating an array of sub-beams each having divergence, the origin of the divergence of each sub-beam lying apart from the respective optical element; first reflecting means for reflecting said array of sub-beams, second reflecting means located relative to said first reflecting means such that a parallel beam impinging on said first reflecting means is reflected from said second reflecting means as a converging beam; the arrangement of said optical elements being such that all incoming sub-beams are directed by said first reflecting means towards said second reflecting means.

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31. Apparatus for use with the method of claim 23, and comprising a source of a high energy beam having a first axis extending in a first direction; an assembly comprising a first reflecting surface lying at an angle to said first direction and a second reflecting surface, said first and second reflecting surfaces being fixedly located relative to one another such that

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said high energy beam is reflected by said first reflecting surface towards said second reflecting surface, thereby to both invert said beam and direct said beam along an axis collinear with said first axis extending in a first direction; said assembly being rotatable about said first axis.

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2025 RELEASE UNDER E.O. 14176